

PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

5 To the Commissioner of Patents and Trademarks:

10 Your petitioners, Toshikazu (NMI) HORI, a citizen of  
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1568; Yutaka (NMI) HIRONO, a citizen of Japan and a resident  
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Fairford Way, San Jose, CA 95129; and, Raymond J. SIU, a  
citizen of the United States and a resident of San Francisco,  
California, whose post office address is 33 Santa Cruz Ave.,  
15 San Francisco, CA 94112, pray that letters patent may be  
granted to them for a

VIDEO GLARE REDUCTION

20 set forth in the following specification.

004610-00000000

## VIDEO GLARE REDUCTION

### 1. Field of the Invention

5       The present invention relates to video cameras, and more particularly to methods and circuits for adjusting the dynamic range of video signals to obtain picture details in the shadows without allowing other areas to glare.

### 10   2. Description of the Prior Art

      The typical charge-coupled device (CCD) array can provide as much as 500 mV of dynamic range. But at some point, increasing light levels will not produce increased signal output, because the CCD array will saturate. It is  
15   quite common for a CCD array to be followed by a stage of amplification that limits the dynamic output range of the camera to as little as one-tenth of the range possible. Only a small portion of the linear operating region of the CCD array is used. Such amplifiers also bring up the picture  
20   brightness to make a more pleasing display. Displays taken directly from the CCD array, or where gains in the amplifier are set low, usually result in pictures that appear too dark.

      A user often has to be able to adjust the camera gain to be able to pick out various items-of-interest in a video  
25   picture. For example, various lighting conditions and weather changes can change the optimum gain needed to discern license plate numbers in video images obtained by parking lot cameras. An operator has to vary the camera gain in order to see each car's license plate number clearly. This phenomenon  
30   prevents automatic recognition systems from operating efficiently, and slows down manually operated systems.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a camera system that can better use the dynamic range of a CCD image array.

It is another object of the present invention to provide a CCD imaging system that is inexpensive to manufacture.

Briefly, a CCD video camera system embodiment of the present invention comprises a CCD imaging device connected to a low-gain amplifier. An analog-to-digital converter converts the analog output of the amplifier to a full-range digital video signal. Such addresses a digital look-up table to produce a digital video output according to one of several selectable range-correction curves. Such range-correction curves comprise two linear slopes that join at one knee or three slopes joined by two knees. Each the linear parts have different gain slopes. The range-correction curves are selected on the basis of the gain slope of the linear slopes, and the knee-points.

An advantage of the present invention is that a CCD camera system is provided that can provide increased image details in darker areas of a picture.

Another advantage of the present invention is that a CCD imaging system is provided that can be used in systems that automatically adapt to a variety of lighting conditions and imaging targets.

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiments which are illustrated in the drawing figures.

IN THE DRAWINGS

Fig. 1 is a functional block diagram of a camera system embodiment of the present invention; and

5 Fig. 2 is a graph representing the dual-slope transfer functions that can be stored as digital tables in the look-up table of Fig. 1.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A camera system embodiment of the present invention is illustrated in Fig. 1 and is referred to herein by the  
15 general reference numeral 100. The system 100 includes a CCD-imaging device 102 that produces a CCD-signal 104. An amplifier 106 set at a relatively low gain by an adjustment 108 helps produce an amplified analog signal 110. An analog-to-digital converter (ADC) 112 produces, e.g., a ten-bit  
20 digital video output signal 114. The gain of amplifier 106 is preferably set so that the dynamic output range of CCD 102 matches the digital dynamic range of ADC 112. A look-up table (LUT) 116 converts each digital input word in digital video output signal 114 to a modified word in a system output  
25 signal 118, e.g., an eight-bit value. A curve-selection signal 120, e.g., a four-bit digital value, is used to choose which predetermined correction curve inside LUT 116 is to be used. Each range-correction curve comprises two linear slopes that join at a knee and have different gain slopes.  
30 The range-correction curves are selected on the basis of the gain slope of the first of the two linear slopes, and the knee-point.

Therefore, the LUT 116 is not used to store the equivalent of a "gamma-correction" curve, which is a

continuous algebraic function and usually implemented with analog techniques. Embodiments of the present invention use only dual-slope compensation conversions that can be precisely controlled with digital techniques and devices.

- 5 Such also are not continuous algebraic functions, and comprise exactly two linear segments with different gains and joined at a knee-point.

In alternative embodiments of the present invention, the LUT 116 is programmable and downloadable. Such can be useful  
10 to load and store the initial look-up tables stored by LUT 116 and selected by signal 120. If LUT 116 is made programmable and downloadable, such can also be useful in applications where the optimum dual-slope compensation conversions need to be empirically derived.

15 For example, a download and reprogramming controller 122 receives new dual-slope transfer functions to load in LUT 116 from a program data signal 124 at a serial input port. The LUT 116 is placed in a reprogramming mode. An address output signal 126 and a selection output signal force an address on  
20 the LUT 116 and a data output 130 forces a new write data on the data ports of the LUT 116. For example, the controller 122 can be a flash memory controller and the LUT 116 can be a flash memory device.

Fig. 2 represents a digital transfer function 200 that  
25 is preferably embodied in the LUT 116 (Fig. 1). Such LUT 116 can be implemented with a programmable read only memory (PROM), e.g., FLASH memory. In one embodiment of camera system 100, the LUT 116 preferably has a ten-bit input address and an eight-bit data output. Therefore, the digital  
30 transfer function 200 is illustrated in Fig. 2 with a X-coordinate that ranges from digital binary 00,0000,0000 at zero to 11,1111,1111 at full scale. Such input produces a transfer function that outputs on the Y-coordinate that

ranges from digital binary 0000,0000 at zero to 1111,1111 at full scale.

A number of selectable transfer functions are shown included in the digital transfer function 200. A straight  
5 linear transfer function 202 is included for illustration purposes only. A linear transfer function could be included in LUT 116, but probably would not be used in most applications of camera system 100. A first dual-slope transfer function has a high-gain linear slope 204 that  
10 breaks at a knee-point 206 and continues in a lower-gain linear slope 208. A second dual-slope transfer function has a high-gain linear slope 210 that breaks at a knee-point 212 and continues in a lower-gain linear slope 214. A third dual-slope transfer function has a high-gain linear slope 216  
15 that breaks at a knee-point 218 and continues in a lower-gain linear slope 220.

A fourth transfer function is different. A high gain linear slope 215 is needed in the mid-range. It ranges between a pair of knee-points 216 and 217. A pair of lower  
20 gain slopes 218 and 219 are used in the extremes of dark and light.

In alternative embodiments of the present invention, three or more knee-points are used and are joined by a multitude of interconnection linear slopes of various gains.  
25 It can happen in particular applications that more than one portion of the dynamic range requires high-gain.

The LUT 116 could contain many more such dual-slope and multi-slope transfer functions all selectable by signal 120. Those illustrated in Fig. 2 are simply used to describe the  
30 concepts needed for successful implementations.

The lower ranges of the input address and output data in Fig. 2 represent the darker scenes in a digital video image. The increased gains represented by slopes 204, 210, and 216, over linear slope 202, produces video images with enhanced

details. One or more of these may be preferred by a user or automatic image recognition system to pull up details of interest in a particular video frame.

In alternative embodiments of the present invention, a particular one of the dual-slope transfer functions 204-220 may be applied to every pixel in a video frame. Or, the dual-slope transfer functions 204-220 may be applied one at a time to sections of a video frame. For example, the top half of a video frame may produce better images for things-of-interest if the dual transfer function 204-208 is selected. But, the bottom half of the video frame may produce better images for things-of-interest if the dual transfer function 210-214 is selected. Of course, the opposite can be implemented wherein the brighter or top-end range has the most gain. In Fig. 2, such would involve knee-points that are below linear slope 202.

Embodiments of the present invention are particularly useful in manufacturing quality control. For example, fine scratches in the surfaces of silicon wafers and chips can be discerned even in the presence of shimmer, glare, and reflections. In the automated manufacturing of glass bottles and containers, cracks and other defects in the glass itself can be spotted even when the lighting conditions are otherwise adverse. In some applications, backlighting needed to candle the pieces can be eliminated. Even sunset lighting conditions that can ordinarily produce impossible glare conditions can be tolerated in automatic vehicle license plate recognition systems.

Some prior art devices apply image processing techniques where the gain of darker or lighter video frames has increased gain, but such do not have the full dynamic range of the original CCD output 104 to work with. Therefore, a large amount of possible resolution is unavailable in such prior art devices.

What is claimed is:

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